



Cooperation under uncertainty: Assessing the value of risk sharing and determining the optimal risk-sharing rule for agents with pre-existing business and diverging risk attitudes

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Abstract

The allocation of risk among the cooperating parties in a shared project is an important decision. This is especially true in the case of large infrastructure investments. Existing risk allocation methods are either simplistic or do not consider the effect of the agents' pre-existing businesses. In this paper, we model and analyse the effect of risk sharing when two agents want to co-develop an energy infrastructure project in an uncertain environment. The cooperating agents have a pre-existing risky business, and the new common project has a deterministic initial cost but random revenue potential. Our analysis shows that the optimal risk-sharing rule depends not only on the agents' risk aversions but also on the volatility of the common project profit, the volatilities of the agents' pre-existing businesses and the correlation of each agent's pre-existing business with the common project. An illustrative example based on energy infrastructure is used to show the implications of the sharing rule for partners.

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1. Introduction

The selection of partners in a joint venture and the allocation of risk among them are important decisions that have a deep impact on the success of the project. However, the existing methods in the literature only consider the agent's risk aversion, leading to the least risk-averse agent taking a higher share of the risk. However, determining the best risk-sharing approach should take other factors into account such as the agent's pre-existing businesses. This paper answers this question, developing a model to determine the value of risk sharing – that is, how much value the coalition brings with respect to the project being developed by a single partner. Contrary to

existing approaches, our developed value of risk sharing considers the agents' pre-existing business and their correlation to the joint venture, together with their risk attitudes. The model provides valuable insights for the most favourable design of a coalition and the risk-sharing contract in order to get the most of the benefits of cooperation.

Cooperation is even more important in infrastructure projects given their high capital intensity, which makes it necessary to form partnerships face the needs for investment in an efficient way. Specifically, the energy sector has recently experienced an increased need for cooperation which we would like to highlight, as it provides a further specific context for this need. Agents in the energy sector are increasingly seeking cooperation to cope with the competitive and complex energy landscape caused by forces such as liberalization, deregulation, renewable energy integration, and climate policies (Ligtvoet, 2013). This can be seen in several large scale joint infrastructure project

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initiatives and plans. For example, in the USA, regional transmission operators are cooperating to develop inter-regional electricity transmission lines to facilitate the integration of renewable energy sources that span across multiple regions (MIT Energy Initiative, 2011). In Europe, bordering transmission operators are cooperating to invest in cross-border transmission to facilitate electricity market integration (Brancucci Martínez-Anido, 2013). Moreover, new regulatory frameworks are being introduced to encourage cooperation in electricity markets integration (Böckers et al., 2013), renewable energy integration (EU Commission, 2006), electricity and gas infrastructure development and upgrade (Henry et al., 2014; Brancucci Martínez-Anido, 2013), energy efficiency (Nauleau et al., 2015), and CO₂ emission reduction (RCI, 2011).

The rationale for cooperation in infrastructure projects is multiple: it enables agents to minimize the effects of uncertainty by aligning their interests (Ligtvoet, 2013); provides strategic advantages such as the ability to achieve objectives faster, getting access to know-how or to markets, cost advantages, transfer or complementarity of technologies, and economies of scale (Williamson, 1979; Bronder and Pritzl, 1992; Guoa et al., 2014). However, cooperation is not always straightforward, and various uncertain factors expose parties to different kinds of risks (Lam, 1999; EU Commission, 2006). On the one hand, large-scale infrastructure projects are particularly subject to risk due to large initial costs, high irreversibility (sunk costs), and long-term durability of assets (Lam, 1999; Boatenga et al., 2015). On the other hand, cooperation involving infrastructure (and energy infrastructure in particular) is complex as multiple agents are involved with different objectives and constraints. By its own nature, cooperation is a multi-motive game. Because each party displays a rational behaviour, there are considerable costs and risks involved in the decision to join a project (Williamson, 1979; Nooteboom, 2000). The presence of endogenous uncertainty (e.g. strategic behaviour) (Berger and Hershey, 1994; Grundy, 2000) and exogenous uncertainty (e.g. technology, market, regulatory changes) often lead to a deadlock in which decision-making stagnates as parties become increasingly risk averse and are afraid to ‘bet on the wrong horse’ (McCarter et al., 2010; Gong et al., 2009). Therefore, with incentives on one hand and costs and risks on the other, the challenges in most infrastructure development cooperation projects are: (1) How will the associated risk and value be shared among the partners? (2) How should we structure contracts to enhance synergies at an acceptable level of risk?

In the strategic management literature, the discussion on the allocation of benefits and risks from cooperation under uncertainty is based on two perspectives: a value-creation perspective and a risk-sharing perspective. The value-creation perspective takes the view that agents cooperate to gain value and hence focuses on the allocation of value from cooperation (Folta and Miller, 2002; Holta et al., 2000). In that respect, real-options valuation is receiving increasing attention as a tool to analyse the value of cooperation, see for example (Kogut, 1991; Liu et al., 2014; Park et al., 2013). The risk-sharing perspective uses the concept of risk sharing to explain the motive for cooperation and allocation of risk among cooperative agents

(see for example Allen and Lueck, 1999; Medda, 2007; Blenman and Xu, 2009).

Regarding the allocation of value from cooperation, the literature has also come a long way from deterministic cooperative game theory models of Nash (1950), Nash (1953) and Shapley (1953) to models for stochastic payoffs (Suijs et al., 1999; Savva and Scholtes, 2005). The literature on optimal risk sharing between two parties was first analysed by Borch for the specific case of insurance contracts (Borch, 1962). Later, Wilson led the research for efficient risk sharing in syndicates (Wilson, 1968) and more recently this was advanced by Pratt (Pratt, 2000). Various risk-sharing allocation techniques have been presented for infrastructure investments. (Lam et al., 2007) used qualitative risk allocation for construction projects using a fuzzy inference mechanism. Medda (2007) used a game theoretical approach to the allocation of risks in transport public-private partnerships. Other techniques applied to this problem include Artificial Neural Networks (Jin and Zhang, 2011) or fuzzy system dynamics (Nasirzadeha et al., 2014). However, all these previous works largely focus on closed contracts where the only payoff comes from the joint investment, and the effects of the agents’ pre-existing businesses are ignored. Moreover, the methods used to model the uncertainty in the future performance of the common project are either deterministic or relatively simplistic, while the future revenues from most infrastructure investments are stochastic.

In this study, we deal with stochastic revenue and consider the correlation of the pre-existing businesses of cooperating agents with the common project. We use concepts from the risk-sharing literature to model a risk-sharing contract between two risk-averse agents who invest in a common project. Then, we apply cooperative game theory to analyse the synergy effects of risk sharing. A stylized case example loosely inspired by a joint venture created to develop a merchant electricity interconnector between the Netherlands and the UK, known as BritNed (BritNed, 2015) is used to illustrate the implications of this research.

This paper adds to the existent literature in two ways: we study the value of cooperation considering that the participants have pre-existing businesses that are correlated with the joint venture and that these agents can have diverging risks attitudes. We also develop the rule for optimal risk sharing –i.e. how much of the risk should be borne by each agent-. These results can be used to select among possible partners so that the value of cooperation is better and to support negotiations.

The paper is organized as follows. Section 1 introduces the work. Section 2 provides the basic model set-up and assumptions. Section 3 solves for the optimal linear contract between the two agents. Section 4 introduces uncertainty in the form of difference in contract design between cooperating parties and solves for the real option value of risk sharing. Section 5 presents computational results and analysis of optimal risk share and values of risk sharing.

2. Modelling revenue and profit

Let’s take two agents ($i=1,2$) who intend to create a joint venture to share the development cost and future profit of an

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